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CHEMISTRY FOR THE SAFETY MAN. SAFETY IN INDUSTRY--ENVIRONMENTAL AND CHEMICAL HAZARDS SERVICES.
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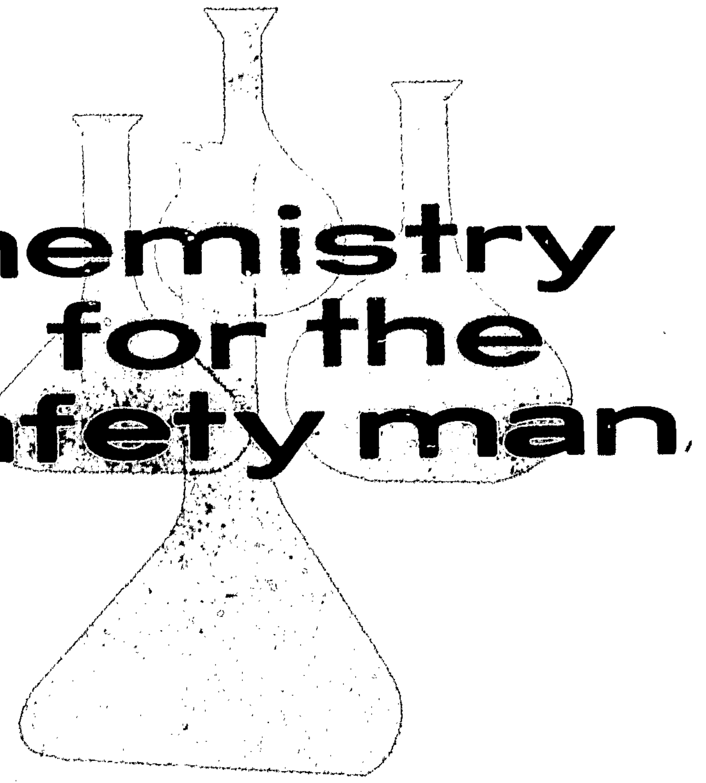
THIS BULLETIN, ONE OF A SERIES ON SAFETY IN INDUSTRY, IS INTENDED TO PROVIDE THE BACKGROUND WHICH WILL ENABLE THE SAFETY MAN TO UNDERSTAND SOME OF THE PRINCIPLES APPLIED IN CONTROLLING CHEMICAL HAZARDS. IT WAS PREPARED IN THE OFFICE OF OCCUPATIONAL SAFETY, DIVISION OF PROGRAMING AND RESEARCH, BUREAU OF LABOR STANDARDS. TOPICS INCLUDE (1) WHAT IS CHEMISTRY, (2) DEFINITION AND PROPERTIES OF MATTER, (3) DESCRIPTION AND CHARACTERISTICS OF SOME IMPORTANT CHEMICALS, (4) FLAMMABLE AND COMBUSTIBLE LIQUIDS, AND (5) DETERMINING THE PROPERTIES OF CHEMICALS. THE DOCUMENT SIZE IS 6 BY 9 INCHES. IT IS ALSO AVAILABLE AS GPO NUMBER L16.3--222 FOR 15 CENTS FROM THE SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C. 20402. (PS)

SAFETY IN INDUSTRY

ENVIRONMENTAL AND CHEMICAL HAZARDS SERIES



chemistry for the safety man

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CONTENTS

Safety in Industry

ENVIRONMENTAL AND CHEMICAL HAZARDS

CHEMISTRY FOR THE SAFETY MAN

MOST industrial processes involve chemistry in one form or another, and a basic knowledge of the fundamentals of chemistry is a prerequisite of a good safety man. The bulletin, one of a series on Safety in Industry, is intended to provide the background which will enable the safety man to understand some of the principles applied in controlling chemical hazards. It should also help in recognizing the existence of hazards and to suggest means of eliminating or controlling them. If nothing more than an understanding of chemical terms is gained, that in itself should make his work more effective.

★ ★ ★

The average person without a good knowledge of chemistry thinks of it as a very special and difficult subject. This is true with respect to the field of the professional chemist or chemical engineer, but it is not true as applied to the knowledge of chemistry needed for an understanding of the hazards presented by the commonly used materials.

Chemistry is so basic to modern civilization that everyone has absorbed a certain amount of chemical knowledge without recognizing it as such. For example, when wood is burned in a fireplace the heat and light given off are largely produced by the carbon of the wood combining with the oxygen of the air. We do not think of this as a chemical reaction, but of course it is. Most people know also that if one "dampers down" a coal stove or furnace, so that it does not get enough air (oxygen), it is likely to give off a deadly gas commonly called coal gas. This is due to the nature of the chemical reaction between carbon and oxygen. Carbon combines first with oxygen to form carbon monoxide which then combines with more oxygen to form carbon dioxide. This second reaction takes place only at high temperature; therefore, if enough oxygen does not get to the carbon monoxide to convert it to carbon dioxide before it has passed out of the high temperature zone in the flame, it will remain carbon monoxide. Under ordinary circumstances of sufficient air and heat, carbon dioxide is produced. In this case, the two reactions take place simultaneously and, in effect, constitute a single reaction. That many people overlook the fact that air and heat are necessary for combustion is proved by the recurrent cases of death, or near death, from furnaces, cook stoves, and heaters that do not get enough air for proper combustion to take place.

Few people realize what a vital part chemistry plays in our everyday living. We get up in the morning after sleeping between sheets that have been bleached by the use of a chemical; we shower with water that has been chemically purified; the soap used is a highly refined chemical product; so is the toothpaste and in all probability the toothbrush itself. At least part of the food served at breakfast has been treated by chemicals in one way or another to preserve it or enhance its value. We drive to work in a car, the power for which is produced by gasoline, which in turn is the end product of a complex and accurately controlled series of chemical processes. The same could be said of the lubricating oil. Probably the seat covers are of plastic, another complex chemical compound. And so it goes through the day. Almost every article we use or work with, many of the things we eat, the clothing we wear, the paving we walk on are wholly or in part chemical in nature or fashioned, partly at least, as a result of chemical processes.

We now know that plant growth is the result of a series of chemical processes. The plant takes in oxygen in the form of carbon dioxide through its leaves, draws water and various elements and compounds from the soil through its roots, and, using the energy supplied by the sun, forms these into the various chemicals that make up the structure of the plant, its flowers, and its seeds. The process by which animals grow and live is complicated and diverse, but it is chemical in nature also. Man has made a start, but only a start, in finding out what these processes are. He has learned how to duplicate many animal or plant-made substances—synthetic rubber for example—in the laboratory. In a few cases the factory-made product is purer or cheaper or better than its counterpart found in the natural state.

WHAT IS CHEMISTRY?

Chemistry is the science that deals with the compounds that the elements form with one another, the properties of those compounds, and the changes in composition that these compounds can undergo.

Element

An element is a substance which cannot be simplified or broken down by ordinary chemical means. The metals, for example, copper, aluminum, and lead are elements; so are the gases, oxygen, hydrogen, and nitrogen; so are carbon, sulfur, and iodine.

About 90 elements exist naturally while a number of others have been made in atom smashers. That, however, is in the field of nuclear physics with which we are not concerned here.

For the purposes of this bulletin, it is necessary to deal with only a few of the elements which constitute those most commonly found in the chemical products with which we are concerned. Similarly we will deal with only the most common or important compounds these elements form with one another.

The following are ordinarily referred to as common elements.

Name	Symbol	Name	Symbol
Aluminum	Al	Magnesium	Mg
Antimony	Sb	Manganese	Mn
Arsenic	As	Mercury	Hg
Barium	Ba	Nickel	Ni
Bismuth	Bi	Nitrogen	N
Bromine	Br	Oxygen	O
Calcium	Ca	Phosphorus	P
Carbon	C	Potassium	K
Chlorine	Cl	Silicon	Si
Copper	Cu	Silver	Ag
Fluorine	F	Sodium	Na
Gold	Au	Strontium	Sr
Hydrogen	H	Sulfur	S
Iodine	I	Tin	Sn
Iron	Fe	Tungsten	W
Lead	Pb	Zinc	Zn

A complete list of elements, along with their atomic numbers, is contained on the inside back cover.

For convenience, each element has been given a symbol which is usually the first letter or the first two letters of its name. For example, O is the symbol for oxygen, C stands for carbon, Al for aluminum, S for sulfur. In some cases the symbol is taken from the Latin name of the element. For example, Fe for iron (ferrum); Pb for lead (plumbum); Na for sodium (natrium). Note that only the first letter of a symbol is capitalized.

Compound

A compound is made up of two or more elements chemically united in definite proportions by weight. For a compound to be formed from the separate elements a chemical reaction must take place. By chemical reaction is meant the combining of the molecules of one substance with the molecules of another substance to produce a new substance, heat being given off or absorbed in the process. For example, sodium and chlorine are elements. At ordinary temperatures sodium is a soft, silvery colored metal. Chlorine is a yellowish gas. The two combine in a vigorous chemical reaction to form sodium chloride (ordinary table salt).

Well over five hundred thousand chemical compounds are known, and more are continually being discovered. Since there are some 90 natural elements, the number of compounds that could theoretically be formed from them is practically limitless.

Atom and Molecule

An atom is the smallest particle of an element that can exist and have the distinctive properties of the element. All compounds, as the definition given above indicates, are made up from a combination of one or more atoms of each of the elements in the compound. The smallest particle of a compound that can exist as a compound is the molecule. Again referring to the fireplace fire, when one atom of carbon (C) unites with one atom of oxygen (O) it forms one molecule of carbon monoxide (CO). A molecule of CO can combine with another atom of oxygen (O) to form one molecule of carbon dioxide (CO_2).

Molecules are so small that it is difficult to realize their minute size. Atomic scientists tell us that if a drop of water were magnified to the size of the earth (8,000 miles in diameter) its molecules would be the size of baseballs. Also, they would be in continuous rapid motion. If you heated your world-size drop of water in a super-world-size tea kettle, its molecules would really be moving around in there and shooting out the spout in the form of steam.

Chemical Symbols

The chemical symbols are so universally used to indicate the chemical compounds that every safety man should know the symbols of at least the common elements. These symbols make possible a simple means of indicating the makeup (chemical formula) of each compound. For example, the formula for carbon monoxide is CO, which shows that each molecule of carbon monoxide is made up of one atom each of carbon and oxygen. Where there is more than one atom of an element in a compound a subscript is used to show it. For example, carbon dioxide is CO_2, meaning that one carbon and two oxygen atoms have combined. Water is H_2O. By adding another atom of oxygen to H_2O we get hydrogen peroxide H_2O_2, a mild solution which has long been used by women to change their brown tresses to blond. When concentrated it is a dangerously corrosive chemical. What a difference that extra little atom of oxygen makes!

We need not concern ourselves with the highly complex compounds of organic chemistry. Even the chemist uses the name if the formula is long. If it has a short trade name he will probably use that. For example, the formula for the widely used insecticide DDT is $(ClC_6H_4)_2\ CHCCl_3$. Its chemical name is dichloro-diphenyl-trichloroethane. No one will ever expect anyone but a chemist to know its chemical name let alone its chemical formula. But a safety man should recognize the formula, as well as the name, for many of the chemical compounds he will encounter. Here are a few to start with.

Inorganic Compounds

Sulfuric acid—H_2SO_4
Nitric acid—HNO_3
Hydrochloric acid—HCl
Ammonia—NH_3
Caustic soda (lye)—$NaOH$
Caustic potash—KOH

Organic Compounds

Carbon tetrachloride—CCl_4
Ethyl alcohol (grain alcohol)—C_2H_5OH
Benzene (benzol)—C_6H_6
Toluene—$CH_3C_6H_5$
Methyl alcohol (methanol)—CH_3OH

Chemical Equations

The use of a symbol for each element also makes it possible to show by a sort of chemical shorthand what occurs in each chemical reaction. The chemist described what happens in our fireplace fire by the equation $C + O = CO$. This says that each atom of carbon in the wood combines with an atom of oxygen from the air to form a molecule of carbon monoxide. But when these two combine they get hot, so to give the full picture we write the equation as $C + O = CO + \text{heat}$. If this molecule of CO meets some more oxygen before it cools down too much, it enters into a second reaction and gives off more heat. This is indicated by $CO + O = CO_2 + \text{heat}$. As previously mentioned, the two reactions are usually simultaneous so the equation is $C + O_2 = CO_2 + \text{heat}$.

MATTER

Matter is generally defined as anything that occupies space and has weight. It is obvious that a block of wood or a piece of iron takes up space and has weight. It is not so easy to see that this applies also to a gas or a mixture of gases, but when you undertake to pump up a tire or blow up a toy balloon you discover that air does take up space. If you get caught in a heavy wind you realize that it must have weight also, otherwise it could not push you around.

There are three states of matter; namely, solids, liquids and gases. A solid has a definite shape and a definite volume, and it resists any force tending to change either its shape or its volume. A liquid occupies a definite volume but it takes the shape of whatever vessel it is in. A gas has neither definite volume nor definite shape. If it is put into a closed vessel it will expand to the limits of that vessel. Also, it can easily be squeezed into a smaller volume as, for example, in the cylinder of an air compressor.

A good example of these three states of matter is furnished by a block of ice. As ice it is a solid, the shape of which can be changed by moderate force, but its volume can be changed only by a very great force; i.e., ice is only very slightly compressible. If its temperature is raised it melts, that is, it passes into the liquid state as water. Its shape then will depend on the vessel it is in, or if spilled on the ground it will flow into whatever cavities and spaces there are between the particles that make up the soil. As water, its volume can be changed very little because, like ice, it is nearly incompressible. Heated to boiling in an open vessel, it changes to a gas or vapor and will expand and disappear completely in the air. Heated in a closed vessel, the vapor is retained in the form of steam, causing pressure on the sides of the vessel.

This expansion due to the change from the liquid to the gaseous state by heating is extremely important. Without it there would be no steam engines or steam power plants. This has its bad side too, for it causes boiler explosions and furnishes most of the explosive force of volcanoes.

Few substances can change as readily under normal conditions into the three states of matter as water. But the safety man should recognize that change in the state of matter, as from solid to liquid to gaseous, occurs in many chemical processes. The degree of expansion when changing from one state to another (liquid to gas) has marked safety implications.

Vapor

The term vapor is applied to the gaseous form of substances that at ordinary temperature can exist both as a gas and as either a liquid or a solid. For example, gasoline, normally a liquid, vaporizes to produce a gas which when mixed with the correct amount of air makes our automobiles run. Water at all ordinary temperatures evaporates to form a gas which we ordinarily refer to as water vapor. Vapors are often a nuisance, a byproduct of the use of the liquid or solid producing them. They are also used to do work, such as vapor degreasing. Many vapors are toxic, for example, the vapor of carbon tetrachloride; and the safety man should be on guard whenever vapors are encountered.

Dust

For all practical purposes we can define dusts as particles of solid matter divided by abrasion and fine enough to float along and to be distributed by ordinary air motion. This, of course, means bad air for breathing and if the dust is combustible a fire and explosion hazard as well.

Fume

Fumes are particles of solid matter also, but the term fume is correct only for particles formed when vapors are condensed from heating metals or other substances.

Mist

Mists are droplets of liquid so fine that they float in the air. They may be formed by condensation from the gaseous form (example, fog above a pond on a still cold morning), by gas escaping from a liquid and carrying fine droplets with it (example, chromium plating tank), or by breaking a liquid up into a very fine spray (example, air brushing).

Properties of Matter

Substances have two kinds of properties, that is, physical properties and chemical properties. Physical properties are such things as color, odor, taste, density, and solubility. By chemical properties we mean the way the elements or compounds react with other elements or compounds. Some react easily with many others. We speak of them as chemically active. For example, nitric acid vigorously attacks a very wide range of substances; therefore, we say it is very active. Other substances, for example, lead, zinc, and chalk react easily with relatively few things and are referred to as relatively inactive. Some substances, for example, gold, asbestos, sand are still more inactive and are useful for that reason. Several of the gaseous elements, of which the two best known are helium and argon, will not combine chemically with any other substance whatever and are termed inert. Sometimes they are useful to the chemist for this reason. For example, helium can be used to exclude air from closed tanks in which oxygen-hungry chemicals are being processed.

Energy

Energy is generally defined as the capacity to do work. There are several different forms of energy. We refer to the energy of a moving

767-140°—65——2

machine as mechanical energy. Heat is another form of energy, so is electricity. When we use the term electrical energy we mean the energy of a power circuit or a battery. We also have radiant energy of which light is the visible form. Energy is never lost, only changed from one form to another. In this discussion we deal primarily with chemical energy because energy is involved in every chemical reaction.

Energy can be in motion or it can be at rest. Energy in motion is illustrated by winds, running water, a man's body falling from a ladder, a moving automobile, or a jet plane streaking across the sky. The energy of motion is called "kinetic" energy—from a Greek word meaning "to move."

Energy at rest is illustrated by the energy stored in coal, or in a tightly wound watch spring, or in water behind a dam. We call this energy at rest "potential" energy because it can be turned into active energy, motion, heat, or electricity. The energy of coal can be released to drive a steam engine, the watch spring can drive the hands of the watch, the water behind the dam can run a turbo-generator.

Molecular Motion

Solid matter—a block of ice, a steel bar, a piece of cheese—is made up of molecules that stay in their place; they vibrate back and forth but do not move around. That vibration makes itself known to us as temperatures. The faster the vibration the higher the temperature. Molecular vibration (heat) is, therefore, in reality a form of kinetic energy, the energy of molecular motion.

Liquids have molecular motion too, but instead of vibrating as in a solid, the molecules move around in all directions continuously colliding and bouncing off one another. If you heat a solid that can melt—ice or iron for example—the melting point is the temperature at which the kinetic energy of the individual molecules overcomes the forces that hold them in their positions and they get loose. Heat a liquid and you further increase the kinetic energy (speed of motion) of the individual molecules. At the boiling point the molecules have obtained enough speed so that they escape from the liquid and shoot out into the air much faster than in the case of ordinary evaporation.

Gas then is a lot of molecules of some substance (or substances) loose in the space in which they are confined and in endless rapid motion, colliding with one another and with walls, floors, or other solid material that encloses them. If you compress a gas you crowd its molecules closer together and they strike against the walls of the vessel more often. The sum of the incredible billions of blows that the molecules of a gas continuously deliver on the walls of the containing vessel manifests itself as gas pressure. The more the blows the higher the pressure and heat. This also explains why the pressure in a cylinder of oxygen, or in a steam boiler, goes up as you heat it. As the temperature goes up—that is, as the molecules increase their speed, each one hits harder and also makes more hits per second because it moves faster.

Heat

As previously mentioned, all chemical reactions either give off or absorb heat. Where heat is given off, the reaction is referred to as exothermic, where heat is absorbed the reaction is endothermic. In this discussion we will pay particular attention to reactors that can give off heat rapidly enough to cause fire or explosion, or both. Many commonly used chemicals will react so vigorously with certain other substances as to present this hazard. Our problem is how to control this tendency and prevent such chemical action when we do not want it.

The chemical reactions that absorb heat give us no trouble but some of those that give it off give us plenty—they cause fires and explosions. Everyone who uses or handles chemicals should know what kind of reaction certain ones are likely to have with each other. For example, concentrated sulfuric acid (H_2SO_4) combines with water and gives off heat. If water is poured into it, tremendous heat will be generated and the acid will be spattered all over the place. Instead of adding water to the acid, the acid should be added slowly to the water with constant stirring, which will gradually heat the solution but will not cause a violent reaction.

Electricity

All chemical reactions generate electricity but with few exceptions in amounts too small for any practical purpose. The few exceptions give us our electric batteries. The ordinary dry cell, such as used in flashlights, is packed with chemicals that react when the circuit is closed so that current can flow. When the circuit is broken the reaction stops except for a very slow leakage away from the current. That leakage is why unused dry cells gradually play out.

Wet cells, for example, the ordinary lead storage battery, work on a reversible chemical reaction between lead and sulfuric acid. An electric current flowing into the battery (charging) causes a reaction that changes the electrical energy into chemical energy. When the circuit is closed the reaction reverses and the chemical energy turns back into electricity and flows out again as an electric current. While the voltage of this current is far too low to hurt anyone (usually 6 or 12 volts) battery charging is potentially hazardous because hydrogen is released while charging. Heat or flame can cause an explosion or fire through a wide range of concentrations of hydrogen in the air.

SOME IMPORTANT CHEMICALS

Some chemical elements or compounds are so common that the safety man runs into them every day, even though he may not be aware of them. A brief description of some of them and an understanding of their characteristics will enable the safety man to recognize their potential hazards.

Oxygen

Oxygen is the most abundant element. Air is 21 percent oxygen. Water is 80 percent oxygen. Most rocks contain large percentages of oxygen in combination with other elements. For example, quartz (most sand is nearly pure quartz) is silicon dioxide (SiO_2).

Oxygen is a colorless, odorless, tasteless gas. It is extremely active chemically, always trying to find a willing partner to join up with. As already explained, it joins up with carbon to make carbon dioxide (CO_2). It joins up with hydrogen to make water (H_2O). It joins up with iron to make iron rust or ferric oxide (Fe_2O_3).

Oxygen is absolutely essential to animal life because the intricate chemical processes which sustain life are based on oxygen. Contrariwise plant life is based on carbon dioxide although plants also use oxygen. The leaves of plants take CO_2 from the air, utilize the carbon and some of the oxygen from it, and return oxygen to the air. So, oxygen is continually being used by animals, by burning and other oxidation processes, and is being replaced by plants.

The fact that air is made up the way it is—approximately 21 percent oxygen, 78 percent nitrogen and small amounts of argon, carbon dioxide, and other gases—has a direct bearing on many chemical processes. For example, the higher the proportion of oxygen, the lower the ignition temperature and the faster the burning (oxidation). Steel will not burn in air, that is, it has no ignition temperatures in air, but if you heat the end of a piece of steel wire red hot—about 1200°F—and plunge it into pure oxygen, it will burn brilliantly. That is the action of the cutting torch. A stream of oxygen causes the metal within the stream to burn when flame is applied, and it will burn its way rapidly through steel and most other metals.

Oxidation. Oxidation for our purpose can be considered the process by which oxygen unites directly with other substances. Compounds formed by this reaction are called oxides. CO and CO_2 are oxides of carbon. H_2O and H_2O_2 are oxides of hydrogen. Red lead is one of several different oxides of lead. The rust that forms so quickly on unprotected sheet iron is an oxide of iron. This particular reaction creates a serious safety problem by weakening iron or steel structures so that they cannot carry their intended load.

Oxidation is an exothermic reaction, which means it gives off heat. In such processes as the oxidation of lead or iron, the heat is given off so slowly that it is not noticeable. Substances that oxidize rapidly, however, carbon, hydrogen, gasoline yield so much heat so rapidly that there is fire or explosion, or both. Failure to safeguard or control chemical reactions of this kind, or substances that may so react, causes a great majority of fires and explosions.

When oxidation is rapid enough to give off noticeable light and heat, we call it combustion (burning). A substance that will burn is spoken of as combustible or a combustible. All of the familiar combustibles—wood, coal, cotton, gasoline, grain dust—must be heated to what is referred to as their kindling or ignition temperature for combustion to start. This ignition temperature is high enough with all ordinary combustibles so that with reasonable care we can use them safely in the numberless ways we do. The ignition temperature of most woods is around 500°F. Your cotton pajamas would ignite at about 450°F, your suit of English tweed probably 100° or so higher. But oxidation can give off enough heat to cause spontaneous ignition or combustion. For instance, oil-soaked rags stored in a closet oxidize, giving off heat. The heat is confined in the closet and may raise the temperature to the ignition point, causing spontaneous ignition.

A dust explosion is another case of rapid oxidation of combustible material. Any substance that, once lighted, will continue to burn can cause a dust explosion under the right conditions. Finely ground dust offers a tremendous surface area of dust particles, compared to surface area of the material in solid form. This provides for easier access to oxygen and heat and therefore easier ignition. All that is necessary is to grind it fine enough so that it can form a dust cloud and ignite it with a match or spark. In the open air there will be a puff of flame and smoke; in closed space you'll get the bang. Fire usually follows, particularly if it's a grain elevator or a woodworking plant. Another case of uncontrolled oxidation!

The recipe for a successful dust explosion is to get plenty of very fine dust of some combustible substance (starch is fine) or of a readily oxidizable metal (aluminum or magnesium) and blow it into the air. Then season with a dash of fire (a match, a static spark, almost anything red hot will do) and you get what you asked for. For perfect results, the dust particles should be close together so that the flame will carry from each one to the next but not so close together that there isn't enough oxygen to consume them. When these conditions exist, you have what is commonly called an "explosive concentration."

Most metal dusts will explode. Magnesium is particularly bad. It is so eager to combine with oxygen that in magnesium grinding plants explosion is a practical certainty unless the dust is kept out of the air, and the air kept out of the dust. Many other metals present this hazard. Aluminum, zinc, even iron dust, can explode if it is pure enough and ground fine enough to float in the air.

As already pointed out, air is about 21 percent oxygen. If for any reason this drops to about 16 percent we get short of breath and can stand very little exercise. We soon die if it drops below about 12 percent. This is the reason behind the tragic stories of children being found dead in abandoned refrigerators with the doors intact.

Slow oxidation in a closed space can also use up the oxygen. Over and over again the papers report cases of men being overcome on entering tanks, bins, wells, or silos that have been left closed for some time. The newspaper account of such a tragedy may suggest some mysterious and deadly gas but that merely shows a lack of basic knowledge on the part of the writer of the article. In nearly every case some slow oxidation process has caused an atmosphere deficient in oxygen. The rusting of the inside surface of a tightly closed steel tank has been known to use up so much oxygen that there wasn't enough left in the tank to support life. This is a real hazard aboard ship when someone enters a tank that has been closed for a long time.

Every farmer knows that a pile of green hay or fodder will heat up and may catch fire when stored in a confined space. Probably few of them think of it as oxidation. The phenomenon of spontaneous ignition arises from slow oxidation but requires that the exothermic result of oxidation be confined, thus raising the temperature to the ignition point.

Oxidation is, therefore, of interest to the safety man because it can cause an oxygen deficiency, and it can start a fire.

Hazardous Oxygen-Hungry Substances. Some elements and a number of compounds and substances used in industry are so eager to combine with oxygen and get so hot in doing so that special safeguards must be thrown about their use. Metallic sodium and potassium are so oxygen hungry that they will rapidly decompose water to get it. The hydrogen is set free and thus presents a fire and explosion hazard. Calcium does the same but much more slowly.

Substances With Oxygen to Spare. When gunpowder was invented—probably by the Chinese a thousand or so years ago—they didn't know about oxygen. They did, however, make use of the oxygen hunger of carbon—charcoal in this case—to make their fireworks. They mixed the finely ground charcoal with finely ground saltpeter, (potassium nitrate—KNO_3) a compound that has oxygen to spare. It holds its oxygen rather tightly, however, and therefore, takes more heat that an ordinary spark or a match can supply to set it off. So they added a little sulfur which ignites easily and they had gunpowder.

Although gunpowder is not to be classed as a commonly used industrial chemical, many chemicals that can explode or contribute to explosions under certain conditions are widely used. These range all the way from substances that, like hydrogen peroxide (H_2O_2), contain oxygen that wants to get loose, to those like potassium nitrate (KNO_3) that have plenty of oxygen but hold it rather tightly. They are widely used in industry, particularly in the chemical industries, as oxidizers; that is, to supply oxygen to a substance that doesn't have enough of it.

The hazards involved in most such chemical processes lie in the field of the chemical engineer. It is up to him and the production executives to provide and maintain process controls that are fully adequate. When they fail, explosions and fires may occur that usually involve heavy losses and may cost lives as well.

Plants using only small or moderate amounts of such substances are not apt to have personnel fully informed as to their hazards and aware of the possibilities of fire, explosion or health injury involved in their use. Here the well-informed safety man can render a valuable service. He should find out what hazardous substances are used and check into the methods of storing and handling them. Out of failure to follow a few simple precautions, justified by the nature of widely used hazardous substances, flows a steady stream of trouble. Perhaps the outstanding fruit of failure to handle a familiar hazardous substance properly—ammonium nitrate (NH_4NO_3)—was the Texas City ship explosion in 1947. It cost 550 lives.

Acids, Bases, and Salts

Acids. Acids are compounds that have one or more atoms of loosely held hydrogen. This hydrogen acts as though it were dissatisfied with its partner and is always looking for one it likes better, for example, hydrochloric acid (HCl). The hydrogen atom is so dissatisfied that it will take up with almost anything. Of course, the other partner, chlorine, is not too happy either. For example, when a molecule of HCl meets up with a molecule of ordinary lye (NaOH), they swap partners fast and get hot in doing so. The reaction is $HCl+NaOH=NaCl+H_2O+\text{heat}$. The reaction goes fast and is likely to form steam and cause spattering or explosion.

Three acids are found in every laboratory and many plants, and are so essential that they have been referred to as the workhorses of the chemical industry. They are made and used in amounts of millions of tons per year. These acids are hydrochloric (HCl), sulfuric (H_2SO_4), and nitric (HNO_3). Because of their dissatisfied hydrogen element, they are very active chemically, they attack a very wide variety of substances including human skin and flesh and eyes. They are not flammable, that is they do not burn or explode. There is, however, the ever present possibility of leakage or spillage into materials or substances with which they can react to cause fire or explosion or liberate toxic vapors or gases. Nitric acid in particular is likely to set fire to sawdust, shavings, straw and many other finely divided combustible materials. Both hydrochloric and nitric acids give off gas when heated and, therefore, can burst their containers. The vapors given off by nitric acid when it is heated are very dangerous because, breathed in any considerable amount, they are likely to cause fatal lung damage. The vapors of HCl and H_2SO_4 are so intensely irritating that they are unbreathable. This property is a safeguard because it gives warning of even very low concentration in the air of the workroom. One gets out quickly, if he can, to get his breath and get the sting out of his eyes. If the concentration is high and he can't get out, he dies.

Acids should be stored in cool places away from the sun and well away from other chemicals and waste materials. The possibility of leakage to floors below (if any) should always be taken into account. Where amounts kept are considerable, floors should be impervious, of acid resisting material, and arranged to be hosed down as needed.

Provisions should be made for the safe handling of containers, particularly carboys. Various types of carboy handling equipment (tilters, carriers) are available commercially.

Protective clothing—rubber aprons, gloves, and perhaps acid resisting shoes—should be worn when handling acids. Chemical type goggles or face shields should always be worn when handling or using acids of any kind.

NOTE. Bulletin 265, "The Inorganic Acids," of the U.S. Department of Labor, Bureau of Labor Standards, contains detailed information on the potential hazards connected with the use and handling of acids and recommended procedures for control measures.

Bases. Bases are compounds that have one or more "hydroxyl" groups. A hydroxyl group is an atom of oxygen linked to an atom of hydrogen (OH). Chemically, it acts much as though it were a single atom.

We have two very active bases that are widely used: caustic soda (sodium hydroxide) (NaOH) and caustic potash (potassium hydroxide) (KOH). Their hazards are similar and we treat them alike. They are called "caustics" because they eat most organic substances—skin, fat, flesh, hair, your shoes, the wooden floor. They react with fats to form soap and glycerine. Ordinary lye is NaOH dissolved in water.

These two caustics are marketed and handled in the form of lumps, pellets, sticks, and in cans or drums of light gage sheet steel. The molten caustic is poured into a drum. It hardens on cooling to a white solid mass. The user strips the sheet metal off and chops up or breaks up the caustic into pieces of convenient size. This involves the hazard of flying chips that will stick to sweaty skin and burn. Caustics can cause very serious eye damage. Suitable protective equipment—aprons, gloves, goggles or face shields—must be worn when handling or using caustics. Also, safety should be provided for other nearby workmen.

Calcium (Ca) gives us another widely used base that, while not as caustic as caustic potash or caustic soda, offers hazards. Ordinary limestone is calcium carbonate ($CaCO_3$). When burned in a kiln it gives off CO_2 and becomes quicklime (CaO). If water is added to CaO it swells up, gets hot, and becomes $Ca(OH)_2$ (caustic lime), that is, $CaO+H_2O=Ca(OH)_2$. It will then take CO_2 out of the air, turn the H_2O loose and again becomes $CaCO_3$. This is the reaction by which lime plaster and lime mortar harden.

CaO and $Ca(OH)_2$ are both caustic but are much less so than $NaOH$ and KOH. The fact that quicklime heats up on wetting has caused many fires, particularly in building supply yards. Quicklime is dumped into a wooden bin, the roof leaks, fire starts in the bin and is carried to the nearby lumber. Another lumber yard goes up. Such fires are spectacular and very expensive; all because of failure to store quicklime properly. Quicklime should be stored in concrete bins with leak-proof metal covers, preferably hinged so that they won't be left off or thrown back. Then make doubly sure by having a good roof.

Salts. A salt is a compound, other than water, which is formed by the reaction of an acid with a base. Salts are mostly stable, even-tempered compounds well satisfied with their lot in life. Some of them, however (the offspring of the "per" acids, perchloric acid for example), are very touchy and blow up on very slight provocation. The salts of nitric acid (nitrates) are for the most part fairly stable, but if heated with oxygen-hungry substances they may give up their oxygen and set their nitrogen free without much fuss, or they may start a fire or give off poisonous gases or both. So don't fool with nitrates unless you know them. The same is true of perchlorates and the like, only more so.

Hazardous Metals

Probably few people think of metals as presenting fire hazards but they can and do. As already pointed out, metallic sodium and potassium are so oxygen hungry that they will decompose water to get it. That sets the hydrogen free and yields so much heat that the hydrogen takes fire. These metals are usually kept under kerosene. Obviously something safer than an old tin can, a water pail, or a glass jar should be used to keep these metals in. Also, a safer storage place than a wooden shelf in the stockroom or plant laboratory should be selected.

The safety man should be suspicious of any operation that produces very fine metal dust because, as already explained, many metal dusts mixed with air can explode. In addition, some of them—aluminum, magnesium, zirconium, bronze powder if fine enough—can decompose water and give off hydrogen just as sodium and potassium do but much more slowly. While hydrogen rises and gets away if it can, it may become pocketed under a tight ceiling or the top of a bin. A spark from static or from welding, and the roof or bin cover goes up and probably the plant burns down. Magnesium is particularly bad in this respect. Not only will Mg dust, trimmings, and shavings take fire easily, but once started even parts and castings of some size will burn very vigorously.

Solvents

Everyone knows that if he drops a pinch of salt (NaCl) into a cup of water the salt will dissolve but few people bother their heads about the "hows" and "whys" of it. There would be no point to a presentation here of the theory that explains just what goes on when something dissolves in something else, but some of the facts connected with this process will be helpful to an understanding of the hazards involved.

The water absorbed the salt by separating the salt molecules from one another and allowing them to spread throughout the water. By stirring it a little the salt will be evenly distributed so that every drop of water will have the same amount of salt as every other drop. This is not a chemical reaction; therefore the salt is still salt. If we set the cup aside until the water has dried up—evaporated—we will have our salt back in crystals just as it was before we dropped it in the cup of water.

A liquid that can dissolve substances in that way is called a solvent. The substance dissolved is called a solute. The combination is called a solution—in this case a solution of salt in water. Water will dissolve more substances than any other solvent. Because of that property water is useful to man in a multitude of ways. Take, for example, a bath; what if water wouldn't dissolve the soap?

The solvents we are interested in are those that are hazardous. Some give off vapors that will burn and explode; for example, gasoline, naphtha, benzene, methanol (wood alcohol). Some are extremely toxic and their vapors, if breathed, can poison one; examples, benzene, carbon tetrachloride, methanol. Note that benzene and methanol present both hazards. Carbon tetrachloride, however, can put fires out so it is used in fire extinguishers but its high toxicity places definite limits on its safe use.

Another point to remember is that the higher the temperature the faster the vapors come off from the liquid. So if the process in which the solvent is used heats it up, the hazard is increased. The amount (concentration of vapor in the air) reaches the point at which it can burn or explode, or at which it can poison one more quickly than if it were not heated. That might make it seem that the hazard is greater in hot weather than cold, but this may be offset by the fact that windows and doors are likely to be kept open in summer and kept tightly closed in winter, at least wherever winters are cold.

Hazards in the use of solvents cover two specific areas—health and fire or explosion. Control of the health hazard involves enclosure or ventilation to keep the concentration of vapors below harmful limits. Fire control involves prevention of the initiation and spread of fire and ventilation to keep the vapors below the lower explosive limit. This lower explosive limit may still be too high for safe breathing. There are a great many solvents, and their control is an important function of the safety man.

FLAMMABLE AND COMBUSTIBLE LIQUIDS

Flammable means "will burn readily," "is highly combustible," like gasoline, alcohol, or naphtha. Until recent years the word was not given in the dictionary. Only inflammable was listed. Since, however, the prefix "in" usually means "not," people who are careless of word meanings are likely to be confused. Therefore, the fire prevention groups, NFPA and NBFU, decided to drop the prefix. For years the dictionary makers apparently thought it was a "screwball" idea and wouldn't accept it. Persistence finally won out, however, and even the august dictionary makers have now accepted "flammable" with the comment that in a technical sense in fire prevention it is preferred to "inflammable."

Boiling Point

As already pointed out all liquids evaporate, that is, give off vapors to some extent. The rate at which they give off vapor is different for each liquid and the higher the temperature, the faster the rate of evaporation. The boiling point is defined as the temperature at which the vapor pressure of a liquid is just slightly greater than the total pressure of the surroundings. In nontechnical terms, it is the temperature when bubbles of vapor are formed within the body of the liquid as its temperature is gradually raised. These bubbles escape into the air and speed up the rate of evaporation.

The boiling point of liquids varies considerably, one reason why some antifreezes with a low boiling point are not too satisfactory. The speed with which a liquid boils away will depend upon the amount of heat reaching it. For example, if a pan of water is heated up to its boiling point (212° F at sea level) it will continue to boil without getting any hotter until it is all boiled away. The faster the heat gets to it, the harder it will boil, and the more rapid the rate of evaporation. The extra heat is used in speeding up the evaporation, not in increasing the temperature of the liquid.

Two things determine the rate at which heat will pass from a hot body to a colder one in contact with it. The greater the difference in temperature, the faster the heat will flow. Also, the greater the area of contact between the two bodies, the greater the amount of heat that will pass into the colder body per second or per minute. If you are boiling a pan of water on a gas range, the higher you have the flame the quicker it comes to a boil and the faster it boils away because more of the pan is in contact with the flame.

Flash Point and Ignition Temperature

You may wonder why the above paragraph was written because most adults know this. The purpose was to get the reader to apply these simple principles of heat transfer to flammable liquids in order to understand better the hazards they offer. Suppose instead of boiling a pan of water some housewife is going to surprise hubby with his favorite steak and french fries. She puts on a pan of grease and turns the flame up high while she peels and slices the potatoes. The grease heats up fast and the hotter it gets, the faster the vapors come off from it. Soon they get thick enough to catch fire from the flames licking up the sides of the pan and the housewife has a nasty fire on her hands. When this occurred the temperature of the grease had reached the flash point; that is, the temperature at which the grease is giving off vapors sufficient to form an ignitible mixture. Ignition was caused by the flame from the gas burner. If combustion (burning) continues, the temperature is said to have reached the fire point.

But suppose it's an electric range. It does not heat the grease up quite as fast but if turned to "high" it does very well. The grease has to get hotter though to catch fire because there is no flame to ignite the vapors and the hot element under the pan is pretty well out of reach. Unless the vapors reach some other ignition source there will be no fire until the grease reaches its ignition temperature when it will flash into flame. This "catch fire all by itself" temperature is what is meant by ignition temperature, also known as autoignition temperature. For pot grease it is probably about 500°–550° F. For processed cooking fats, it is perhaps 100° higher—a fairly substantial margin of safety.

Explosive Limits

Perhaps the housewife has the heat under her pan of grease just hot enough to vaporize most of the grease without getting it up to its ignition temperature. The doors to the kitchen are closed. The vapors from the grease get thicker and thicker in the kitchen until the mixture is rich enough to be ignited by the gas flame or the red hot heating element. The percentage of grease vapor in the air that yielded the ignition was the lower explosive limit of the mixture of grease vapor with air. It was probably about 2 to 3 percent. Below its lower explosive limit, no ignition occurs.

But if the percentage of vapor grease in the air continues to increase, and if for some reason it is not ignited, the concentration will in time become so heavy that it cannot be ignited. It has then reached the upper explosive limit. Ignition can occur only between the lower explosive limit and the upper explosive limit.

The difference between the upper and lower explosive limits for any given substance is termed the "explosive range." For gasoline, for example, the lower explosive limit is 1.4 percent, the upper is 7.6 percent. Therefore, its explosive range is from 1.4 to 7.6 percent, a range of 6.2 percent. A gasoline air mixture lower than 1.4 percent of gasoline will not ignite. Neither will one having more than 7.6 percent of gasoline. This is why the carburetor on your car must be set right.

The lower explosive limit of most flammable substances is low; few are over 5 percent. The upper limits vary widely and, therefore, the explosive ranges vary widely. For example, the explosive range of ordinary alcohol is 4.3 to 19 percent, that of natural gas is 4.8 to 13.5 percent, that of hydrogen is 4.1 to 75 percent, and acetylene tops the list with the truly remarkable range of 2.5 to 81 percent. Obviously, the greater the explosive range, the greater the hazard.

Vapor Density

Another property of flammable vapors and gases that affects the hazard they offer is their density in relation to air. The ratio of the mass of a given volume of vapor (or gas) to the same volume of air is its "vapor density." If the vapor density is substantially greater than air (air, being expressed as 1) the vapor (or gas) will tend to settle; if substantially less, it will tend to rise. Also, it will spread through the air (diffuse) at a rate that will depend chiefly on air motion. In perfectly still air the spreading would be slow; in a room with some fans pushing the air around it will spread rapidly.

A heavy vapor like that of amyl alcohol (vapor density 3.04), benzene (vapor density 2.77), naphtha (vapor density 3.70), or turpentine (vapor density 4.84) will flow downhill seeking its level much as water does. It diffuses, too, as it goes. Suppose we put a pan of turpentine or naphtha on a hot plate and heat it up. If we could see the vapor, we could watch it fill the space in the pan above the liquid and then spill over and spread over the floor and into any holes or cracks there might be. At the same time it would be spreading through the air of the room. If there is a hole in the floor around the drain pipe, it would spill through into the basement and spread out and perhaps reach the gas heater pilot. There would be an explosion there in the basement if it had diffused enough to yield a mixture within the explosive limits of any considerable volume. If not, the flame would flash back along the stream of flowing vapor into the kitchen where, in all probability, enough mixture would have occurred to form an explosive mixture. And that is exactly why it is a very unsafe practice to heat volatile liquids of a flammable nature over an open fire.

A few gases that are rather commonly used in industry, or that may be given off in some processes, are lighter than air, and therefore may flow upward. They diffuse, of course, just as the heavier gases and vapors do. Commonest of these are methane (natural gas is mostly methane), ammonia, and hydrogen. Hydrogen really flows upward when it has a chance, because its density is only one fourteenth that of air. So when looking for a pocket of hydrogen, don't look down, look up. Ammonia and methane are just over half as dense as air, so we say that they "tend" to go up which, in everyday English, means that they would rather go up than down. Chiefly they diffuse.

Gases and vapors having about the same density as air—for example, acetylene, carbon monoxide, formaldehyde, hydrogen sulfide, and methyl alcohol—diffuse rather than flow. Instead of looking chiefly up or down for them it would be well to look "all over."

In guessing where a vapor might go when turned loose, one has to take temperature into account. If the vapors are from some process that sets up a column of hot air, like a tank of heated solvents or exhaust from an internal combustion engine, the vapors may be carried upward. They may flow (and diffuse) along under the ceiling, cooling off as they go and tending to fall back to the floor level so that the highest concentration may be in a pit or corner at some distance away from the source of the vapors. This is one reason for exhausting, or at least hooking, all hot air producers up to stacks. But if the fumes or vapors are toxic they should be filtered out or washed out or otherwise safely taken care of to prevent poisoning the neighborhood. Outside is a very big place, but the "Donora" smog and smogs in Los Angeles and other cities are proving that even the air in all outdoors cannot take care of everything we pour into it.

Control of harmful vapors may be effected either through dilution or removal. If diluted, vapor density must be lowered so as to eliminate both health and explosive hazards. If removed at the point of origin, exhaust equipment must be so located as to capture the vapor before it has a chance to escape into the room or workplace. If the vapor is lighter than air, the vapor can be trapped above the liquid; if heavier, below or on a level with it.

Volatility

There is one other property of flammable liquids that is important; namely its volatility—the rate at which it will evaporate. The volatility of a liquid is the rate at which it will evaporate in the open air at a given temperature (assumed to be 70° F. if not otherwise stated). The faster a liquid will evaporate, that is, the higher its volatility, the more quickly its vapors will reach the lower explosive limit in any given situation. The very high volatility of carbon disulfide, together with its low flash point (−22° F.), makes it a very bad actor to fool with.

Classification of Flammable and Combustible Liquids

The 1964–65 issue of the National Fire Codes reports several significant changes in the Flammable and Combustible Liquids Codes. Particularly important is the new classification for flammable and combustible liquids which has been many years in the making. The 1963 edition of the code incorporates the new classification system and alters the one which has been in existence for many years.

The former classification system divided flammable liquids into three major classes. The new classification system divides the flammable liquids into two major classes and Class III is now identified as the "Combustible Liquid" Class.

Flammable Liquids shall mean any liquid having a flash point below 140° F. and having a vapor pressure not exceeding 40 pounds per square inch (absolute) at 100° F.

National Fire Protection Association has divided the flammable liquids into two classes of liquids as follows:

- **Class I** liquids shall include those having flash points below 100° F. and may be subdivided as follows:
    - **Class IA** shall include those having flash points below 73° F. and having a boiling point below 100° F.
    - **Class IB** shall include those having flash points below 73° F. and having a boiling point at or above 100° F.
    - **Class IC** shall include those having flash points at or above 73° F. and below 100° F.
- **Class II** liquids shall include those having flash points at or above 100° F. and below 140° F.

The volatility of liquids is increased when artificially heated to temperatures equal to or higher than their flash points. When so heated Class II and III liquids shall be subject to the applicable requirements for Class I or II liquids. This Code may also be applied to high flash point liquids when so heated even though these same liquids when not heated are outside of its scope.

Combustible Liquids shall mean any liquid having a flash point at or above 140° F. and below 200° F., and shall be known as Class III liquids.

NOTE. The upper limit of 200° F. is given because the application of the Code does not extend to liquids having flash points above 200° F. and should not be construed as indicating that liquids with higher flash points are noncombustible.

DETERMINING THE PROPERTIES OF CHEMICALS

Chemists can tell in a general way what the properties of a chemical are if they know its chemical formula. However, knowledge exact enough to determine accurately such things as melting point, boiling point, degree of toxicity, or ability to cause skin irritation can be gained only by careful testing and research.

In general, manufacturers of chemicals determine the hazards of new chemicals fairly well before putting them on the market. They may or may not make this information readily available to the purchaser. If the information or hazard is not given on the label, the purchaser should get it from the manufacturer and should take steps to see that the necessary controls are established before it is used.

Trade names are extremely valuable in competitive marketing. When applied to products manufactured in strict compliance with adequate standards, they are of great value to the customer as well as to the manufacturer. When, however, they conceal the hazardous nature of a substance (due usually to some hazardous ingredient) they present a danger to the unwary user. This is the "why" of the requirement of the Food and Drugs Act that drugs which may be sold without a prescription must bear a label identifying both the ingredients and the manufacturer.

Because of the changing technology, hundreds of new type chemicals are appearing on the market daily. It is imperative that those concerned with protecting the safety and health of the worker be aware of the hazards connected with these new chemicals. The "Manual of Hazardous Chemical Reactions," NFPA No. 491M serves as an excellent reference in this connection. It assists in identifying many of the chemicals and provides a compilation of chemical reactions that have been reported as potentially dangerous. Particularly interesting is the data relating to factors such as temperature, contaminants, mixtures, etc., that have a profound effect on the cause and rate of reactions.

Labeling Hazardous Chemicals

Of course, identifying the content of a product isn't enough. One must know the conditions and limits of safe use. Since medicines must be approved for sale to the public, the user can be reasonably sure that if he follows the directions on the label he will not be injured. But regulation in the field of occupational safety and health is a State, rather than a Federal, function. While there is much interest among State officials in the labeling of hazardous chemicals, only a few States have labeling laws. Trade name products not under labeling laws may contain hazardous substances. Some of these are widely used. The safety man should be particularly alert for trade name cleaners, degreasers, solvents, paint and lacquer thinners, paint removers and the like, because these may contain such toxic substances as carbon tetrachloride, methanol, toluene, or benzene. Some may contain strong skin irritants or sensitizers. Also, in operations in which dust is produced, as in buffing and polishing, trade name substances should be checked for toxic ingredients.

The use of warning labels is very helpful in giving warning as to the nature of the hazard. It is seldom feasible, however, to put really adequate safe-practice information on a label of reasonable size; therefore the user should regard the information on the labels merely as a guide in developing the safe procedures suited to the exposure involved in each case.

The Manufacturing Chemists' Association is a highly responsible organization whose membership includes practically the entire chemical manufacturing industry in this country. Therefore, the safety information it issues has received wide acceptance as being reliable and authoritative. It publishes "Manual Sheets" and "Data Sheets" concerning the properties and hazards of its products, and has established a system of labels for use on containers in which hazardous chemicals are shipped. These "Manual Sheets" and "Data Sheets" are available to industrial concerns and are a valuable asset to the safety man.

The labels comprise essentially the following information:

(a) Name of product, or its most hazardous ingredient.

(b) Degree of hazard indicated by the use of the signal words "Danger," "Warning," "Caution," in descending order of importance.

(c) The applicable signal word is followed by an affirmative statement of the hazard. Examples are:

Extremely flammable.
Vapor harmful—Poison.
Rapidly absorbed through skin.
Warning—Causes burns.
Vapor irritating.

(d) The statement of hazard is followed by the advisable precautionary measure. Examples:

Keep away from heat and open flames.
Avoid breathing vapor.

Do not get in eyes or on skin.
Wear goggles and rubber gloves when handling.

(e) When advisable, first aid information is included. Examples:
Eyes— Immediately flush with water for at least 15 minutes.
Skin— Immediately remove all contaminated clothing and flush skin with water for at least 15 minutes.
Poison—Suitable antidote suggested.

Interstate Commerce Commission Labels

Partial information on the hazardous properties of chemicals is obtained from labels on the shipping container required by the Interstate Commerce Commission. Regulations of the ICC contain requirements for packaging as well as labeling of hazardous chemicals when shipped in interstate commerce. The absence of an ICC label does not necessarily mean that the commodity is nonhazardous, since ICC regulations do not apply to intrastate transportation, and many hazardous materials, such as flammable liquids with a flash point above 80° F., do not require labels. When carload lots of hazardous materials are shipped in interstate commerce, ICC labels are not required on individual containers.

Examples of ICC labels are as follows:

The labels under discussion are of diamond shape with each side 4 inches long with printing inside of a border measuring 3½ inches on each side of the label.

1. "*Red Label*"—*Black Printing:* Flammable liquids. If the flammable liquid is also a class "A" poison (ICC Classification) or radioactive materials poison "D," the "poison gas" label or "radioactive material" label must also be applied.
2. "*Yellow Label*"—*Black Printing:* Flammable solids and oxidizing materials. If the flammable solid or oxidizing material is also a class "A" poison or radioactive materials poison "D," then the additional appropriate labels must also be applied.
3. "*White Label*"—*Black Printing:* Acids, alkaline caustic liquids or corrosive liquids—(A separate white identification label is used for each article). If the acid, alkaline, caustic liquid or corrosive liquid is also a class "A" poison or radioactive material poison "D," the poison gas label or radioactive materials label must also be applied.
4. "*White Label*"—*Red Printing:* Poisonous articles and poison gas. "Poison" label is required on containers of class "B" poison liquids or solids. If the class "B" poison liquid or solid is also a radioactive material poison "D," the "radioactive materials" label must also be applied. "*Poison gas*" label is required on all containers of class "A" poisons.

5. "*Red Label*"—*Black Printing*
   Compressed Gas—Flammable
   Flammable gas label is required on all containers of flammable compressed gases. If the flammable compressed gas is also a class "A" poison or a radioactive material poison "D," the "poison gas" label or the "radioactive materials" label must also be applied.
6. "*Green Label*"—*Black Printing*
   Compressed Gas—Nonflammable
   If the nonflammable compressed gas is also a class "A" poison or a radioactive material poison "D," the "poison gas" label or "radioactive materials" label must also be applied.
7. "*White Label*"—*Radioactive Materials*
   Groups I and II—*White Label—Red Printing* on containers of radioactive materials class "D" poisons in these groups.
   Group III—*White Label—Blue Printing* on containers in this group class "D" poison, "radioactive material emitting corpuscular rays only."

NOTE:

(a) Special labels are required for shipment of flammable and dangerous materials by air (CFR Title 49, Part 73.405);

(b) Classifications of all poisons referred to herein are those established in the CFR Title 49, Part 72.5 "List of explosives and other dangerous articles," pp. 8–33 (Rev. 1964);

(c) Under certain conditions, all of the above articles are exempt in part from the labeling requirements CFR Title 49, Part 72.

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It is hoped that this brief text on fundamentals of chemistry will enable the safety man to do a better job in suggesting controls to eliminate chemical hazards. Other bulletins in this series will cover specific groups of hazardous chemicals or hazardous environments. They will be published in the Environmental and Chemical Hazards Series, under the general title of Safety in Industry.

REFERENCES

The following references are given as constituting authoritative sources of information in the more technical fields of chemistry as related to problems of the safety man.

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4. N.F.P.A. Handbook of Fire Protection. National Fire Protection Association, Boston, Mass., 02110. 1962.
5. N.F.P.A. Manual of Hazardous Chemical Reactions, N.F.P.A. No. 491M, National Fire Protection Association, Boston, Mass., 02110. 1964.
6. National Fire Codes, Vol. I, Flammable Liquids. National Fire Protection Association, Boston, Mass., 02110. 1964–65.
7. CFR-Code of Federal Regulations, Title 49, Parts 71–90 (Revised as of January 1, 1964), Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402.

In addition, publications of various insurance companies and their associations, literature from manufacturers of chemicals and personal protective equipment, along with chemistry textbooks at the high school or college level contain information which will help the safety man in his day-by-day problems involving chemistry or chemical substances.

U.S. GOVERNMENT PRINTING OFFICE:1965

LIST OF THE ELEMENTS

Atomic Number	*Name*	*Chemical Symbol*	*Atomic Number*	*Name*	*Chemical Symbol*	*Atomic Number*	*Name*	*Chemical Symbol*
1	Hydrogen	H	37	Rubidium	Rb	71	Lutecium	Lu
2	Helium	He	38	Strontium	Sr	72	Hafnium	Hf
3	Lithium	Li	39	Yttrium	Y	73	Tantalum	Ta
4	Beryllium	Be	40	Zirconium	Zr	74	Tungsten	W
5	Boron	B	41	Niobium	Nb	75	Rhenium	Re
6	Carbon	C	42	Molybdenum	Mo	76	Osmium	Os
7	Nitrogen	N	43	Technetium	Tc*	77	Iridium	Ir
8	Oxygen	O	44	Ruthenium	Ru	78	Platinum	Pt
9	Fluorine	F	45	Rhodium	Rh	79	Gold	Au
10	Neon	Ne	46	Palladium	Pd	80	Mercury	Hg
11	Sodium	Na	47	Silver	Ag	81	Thallium	Tl
12	Magnesium	Mg	48	Cadmium	Cd	82	Lead	Pb
13	Aluminum	Al	49	Indium	In	83	Bismuth	Bi
14	Silicon	Si	50	Tin	Sn	84	Polonium	Po
15	Phosphorus	P	51	Antimony	Sb	85	Astatine	At
16	Sulphur	S	52	Tellurium	Te	86	Radon	Rn
17	Chlorine	Cl	53	Iodine	I	87	Fransium	Fr
18	Argon	A	54	Xenon	Xe	88	Radium	Ra
19	Potassium	K	55	Caesium	Cs	89	Actinium	Ac
20	Calcium	Ca	56	Barium	Ba	90	Thorium	Th
21	Scandium	Sc	57	Lanthanum	La	91	Protactinium	Pa
22	Titanium	Ti	58	Cerium	Ce	92	Uranium	U
23	Vanadium	V	59	Praseodymium	Pr	93	Neptunium	Np*
24	Chromium	Cr	60	Neodymium	Nd	94	Plutonium	Pu*
25	Manganese	Mn	61	Promethium	Pm*	95	Americium	Am*
26	Iron	Fe	62	Samarium	Sm	96	Curium	Cm*
27	Cobalt	Co	63	Europium	Eu	97	Berkelium	Bk*
28	Nickel	Ni	64	Gadolinium	Gd	98	Californium	Cf*
29	Copper	Cu	65	Terbium	Tb	99	Einsteinium	E*
30	Zinc	Zn	66	Dysprosium	Dy	100	Fermium	Fm*
31	Gallium	Ga	67	Holmium	Ho	101	Mendelevium	Mv*
32	Germanium	Ge	68	Erbium	Er	102	Nobelium	No*
33	Arsenic	As	69	Thulium	Tm			
34	Selenium	Se	70	Ytterbium	Yb			
35	Bromine	Br						
36	Krypton	Kr						

*Artificial element.